This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

As rescanning documents *will not* correct images, please do not report the images to the Image Problem Mailbox.

[Date of request for examination]	03.03.1999
[Date of sending the examiner's decision of rejection]	
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]	
[Date of final disposal for application]	
[Patent number]	
[Date of registration]	
[Number of appeal against examiner's decision of rejection]	
[Date of requesting appeal against examiner's decision of rejection]	
[Date of extinction of right]	

Copyright (C); 1998 Japanese Patent Office

(19) **JAPANESE PATENT OFFICE (JP)**

(11) **Japanese Laid-Open Patent Application (Kokai) No. H6-304153**

(12) **Official Gazette for Laid-Open Patent Applications (A)**

(51) Int. Cl.[5]		Class. Symbols	JPO File Nos.	F1	Tech. Indic.
A 61 B	5/055				
G 01 R	33/28				
			7507-4C	A 61 B 5/05	370
			8825-4C		366
			9219-2J	G 01 N24/02	Y

(43) Disclosure Date: November 1, 1994

Number of Claims: 3

Request for Examination: Not yet submitted

(Total of 8 pages [in original])

(21) Application No. H5-95927

(22) Filing Date: April 22, 1993

(71) Applicant: 000121936

GE Yokogawa Medical Systems, Ltd.

4-7-127 Asahigaoka, Hino-shi, Tokyo

(72) Inventor: Eiji Yoshitome

c/o GE Yokogawa Medical Systems, Ltd.

4-7-127 Asahigaoka, Hino-shi, Tokyo

(74) Agent: Shinjiro Arichika, Patent Attorney

(54) Title of the Invention: Image pickup apparatus using an MRI device

(57) Summary

Problem: To perform image pickup using an MRI device, while continuously moving the object for imaging.

Configuration: If the length in the direction of movement of the imageable region of the MRI device 10 is Mw, the length in the direction of movement of the range for imaging is Gw, and the time for collection of one image's worth of data is Mt, then a movement/image pickup simultaneous execution unit 11 controls a belt conveyor 20 so as to effect movement at a speed Gv equal to or less than (Mw-Gw)/Mt, and simultaneously executes movement by the belt conveyor 20 and image pickup by the MRI device 10.

Advantageous Result: The image pickup efficiency can be improved.

Claims

Claim 1: Image pickup apparatus using an MRI device, comprising an MRI device, and a movement device to move the object for imaging relative to the MRI device, so as to pass through the bore of the MRI device; characterized in comprising a movement/image pickup simultaneous execution unit which, if the length in the direction of movement of the imageable region of said MRI device is Mw, and the length in the direction of movement of the range for imaging is Gw, controls said movement device so as to move [the object for imaging] at a speed equal to or less than the quotient (Mw-Gw)/Mt of the difference of the two (Mw-Gw) divided by the time Mt for collection of the data for one image, and further executes image pickup by said MRI device simultaneously with said movement.

Claim 2: The image pickup apparatus using an MRI device according to Claim 1, characterized in comprising excitation region following-movement means which performs movement causing the position of the excitation region for each view to follow the relative movement amount when the plane for image pickup is orthogonal to the direction of relative movement.

Claim 3: Image pickup apparatus using an MRI device according to Claim 1, characterized in comprising phase correction means which performs phase correction of the data for each view according to the amount of relative movement, when the plane for image pickup is parallel to the direction of relative movement.

Detailed Description of the Invention

0001

Industrial Field of the Invention

This invention relates to image pickup apparatus using an MRI device, and specifically to an image pickup apparatus which can perform image pickup using the MRI device, while continuously moving the object for imaging.

0002

Prior Art

An image pickup apparatus comprising an MRI device and a movement device which moves the object for imaging so as to pass through the bore of the MRI device is disclosed in, for example, Japanese Patent Laid-open No. 63-272335. When the plane for image pickup is parallel to the movement direction, this conventional image pickup apparatus first stops movement of the object for imaging G, performs image pickup, and obtains a first image of length T in the movement direction. Then, after moving a distance T, movement is again stopped, image pickup is performed, and a second image is obtained of length T in the movement direction. This is repeated n times, and by joining the n images from the first to the nth, an image of length nT is obtained. Fig. 11 shows a schematic diagram of the above conventional image pickup apparatus. G is the object for imaging (the patient); 60 is a cradle for moving the object for imaging G; 50 is the MRI device; and 50a is the bore. 51 is a movement-stopping control unit which stops the cradle 60 for image pickup, and is part of the MRI device 50.

0003

Problem to be Solved by the Invention

In the above conventional image pickup apparatus, the MRI device and movement device do not operate simultaneously. That is, when image pickup is being performed by the MRI device, the movement device is stopped, and during movement by the movement device, the MRI device is stopped. Hence there is the problem that image pickup efficiency is poor. One object of this invention is to provide an image pickup apparatus capable of performing image pickup using the MRI device while continuously moving the object for imaging.

0004

Means to Solve the Problem

The image pickup apparatus using an MRI device of this invention is an image pickup apparatus comprising an MRI device and a movement device which moves the object for imaging relative to the MRI device, so as to pass through the bore of the MRI device; characterized in further comprising movement/image pickup simultaneous execution means which, if the length in the movement direction of the imageable region of the above MRI device is Mw, and the length in the movement direction of the imaging range is Gw, controls the above movement device such that the movement is at a speed Gv equal to or less than the difference of these (Mw-Gw) divided by the time Mt for collection of the data for one image, (Mw-Gw)/Mt, and also simultaneously executes image pickup by the above MRI device. It is preferable that the above image pickup apparatus further comprises excitation region following-movement means such that, when the plane for image pickup is orthogonal to the direction of relative movement, movement is performed to cause the position of the excitation region for each view to follow the amount of relative movement. It is preferable that the above image pickup apparatus further comprises phase correction means such that, when the plane of image pickup is parallel to the direction of relative movement, phase correction of the data for each view is performed according to the amount of relative movement.

0005

Action

In the image pickup apparatus using an MRI device of this invention, if the length in the movement direction of the imageable region of the MRI device is Mw, and the length in the movement direction of the imaging range is Gw, then the movement/image pickup simultaneous execution means controls the movement device such that movement is performed at a speed Gv less than or equal to the difference of the two (Mw-Gw) divided by the time Mt for collection of the data for one image, (Mw-Gw)/Mt. Further, movement by the movement device and image pickup by the MRI device are executed simultaneously. If the above condition of a speed Gv is met, one image's worth of data can be collected during the time that the object for imaging is within the imageable region. And if ultra-high speed image pickup is performed by the MRI device with, for example, Mt within several hundred milliseconds, then even with the speed Gv at a practical speed there is little movement of the object for imaging, so that there is little

blurring and few spurious images, called motion artifacts, and image quality is not greatly degraded. Hence image pickup can be performed while continuously moving the object for imaging, without performing special correction, so that the image pickup efficiency can be improved.

0006

When comprising excitation region following-movement means, and when the plane for image pickup is orthogonal to the direction of relative movement, if the position of the excitation region for each view is moved to follow the amount of relative movement by this excitation region following-movement means, [the effect] is equivalent to the case where the object for imaging is stationary, and no motion artifacts occur. Hence image pickup with high image quality is possible while continuously moving the object for imaging.

0007

When comprising phase correction means, and when the plane for image pickup is parallel to the direction of relative movement, if the data for each view is phase-corrected according to the amount of relative movement by the phase correction means, [the effect] is equivalent to the case where the object for imaging is stationary, and no motion artifacts occur. Hence image pickup with high image quality is possible while continuously moving the object for imaging.

0008

Embodiments

Below, this invention is explained in further detail based on the embodiments shown in the drawings. The [embodiments] do not limit the scope of this invention. Fig. 1 is a schematic diagram of an image pickup apparatus 1 using an MRI device of one embodiment of this invention. G is the object for imaging (not limited to a patient); 20 is a movement device, such as a conveyor belt, which continuously moves the object for imaging G; 10 is the MRI device; and 10a is the bore. The MRI device 10 comprises a movement/image pickup simultaneous execution unit 11; a correction requirement judgment unit 12; an axial view-linked slice movement unit 13; a sagittal/coronal SAT application unit 14; a sagittal/coronal phase correction unit 15; and an oblique/three-dimensional integrated control unit 16.

0009

As shown in Fig. 2, the movement/image pickup simultaneous execution unit 11 controls the belt conveyor 20 to move the object for imaging G at a movement speed Gv. Simultaneously, image pickup is started with repetition time TR (11A). If the length in the movement direction of the imageable region of the MRI device 10 is Mw, and the length in the movement direction of the imaging range is Gw, then when the time to collect one image's worth of data is Mt,

$$Gv \leq (Mw-Gw)/Mt$$

As a result, one image's worth of data can be collected during the time when the object for imaging G is in the imageable region Mw. Fig. 3 shows a schematic diagram of the

case of the maximum condition Gv = (Mw-Gw)/Mt. In general, when one image's worth of data consists of M views,

TR = Mt/M

0010

As shown in Fig. 4, the correction requirement judgment unit 12 first judges whether the movement distance Gv ·Mt during the time for collection of one image's worth of data is sufficiently small (12A). If it is sufficiently small that motion artifacts can be ignored, corrections are judged to be not necessary, and control is returned to the system (EXIT1) without starting the axial view-linked slice movement unit 13, the sagittal/coronal SAT application unit 14, the sagittal/coronal phase correction unit 15, or the oblique/three-dimensional integrated control unit 16. When control is returned via EXIT1, the system reconstructs the image from the collected data. If [the distance] is not sufficiently small, a judgment is made as to whether the image pickup is of an axial image with the imaging plane orthogonal to the direction of relative movement (12B). If axial, the axial view-linked slice movement unit 13 is started (12C). If not axial, a judgment is made as to whether the image pickup is of a sagittal image or a coronal image with the imaging plane parallel to the direction of relative movement (12D). If sagittal or coronal, the sagittal/coronal SAT application unit 14 and sagittal/coronal phase correction unit 15 are started (12E). If neither sagittal nor coronal, a judgment is made as to whether the image pickup is oblique, with the imaging plane inclined with respect to the direction of relative movement, or three-dimensional (12F). If oblique or three-dimensional, the oblique/three-dimensional integrated control unit 16 is started (12G). If neither oblique nor three-dimensional, control is returned to the system (EXIT2) without starting the axial view-linked slice movement unit 13, the sagittal/coronal SAT application unit 14, the sagittal/coronal phase correction unit 15, or the oblique/three-dimensional integrated control unit 16. When control is returned via EXIT2, the system performs error processing.

0011

As shown in Fig. 5, the axial view-linked slice movement unit 13 moves the position of RF excitation/inversion to follow movement of the object for imaging G for each view, and collects data for each view (13A). This axial view-linked slice movement unit 13 is equivalent to excitation region following-movement means. As shown in Fig. 6, the object for imaging G moves by an amount Gv ·TR between views, so that if the RF excitation region Ms also moves by Gv ·TR, [the effect] is equivalent to the case in which the object for imaging G is stationary. Hence image pickup with high image quality while continuously moving the object for imaging G is possible, without the occurrence of motion artifacts. Movement of the RF excitation region Ms is specifically achieved by, for example, changing the RF frequency for each view.

0012

As shown in Fig. 7, the sagittal/coronal SAT application unit 14 adds a spatial SAT pulse, as necessary, prior to the normal pulse sequence, to limit the region of appearance of MR signals according to the position of the object for imaging G for each view. Then, data is

collected for each view (14A). As shown in Fig. 8, the object for imaging G moves through the RF excitation region Ms. Because of this, even MR signals from the same location of the object for imaging G are phase-shifted for each view along whichever of the frequency-axis and the phase-axis direction coincides with the direction of movement. The sagittal/coronal phase correction unit 15 therefore multiplies the data D'(f,p) for each view by either

exp(-j2πfΔx/Fw), where f is the data number in the frequency-axis direction, and is an integer from (-N/2)+1 to N/2, Δx is the phase shift amount from the gradient center, and Fw is the imageable region in the frequency-axis direction, or by

exp(-j2πpΔy/Pw), where p is the data number in the phase-axis direction, and is an integer from (-M/2)+1 to M/2, Δy is the phase shift amount from the gradient center, and Pw is the imageable region in the phase-axis direction. The result is taken to be the view data D(f,p) (15A).

0013

Next, the principle of the above phase correction is explained. As shown in Fig. 9, if the case of movement in the frequency-axis direction is assumed, then the MR signals D(f,p) from a signal source g(x,y) in real space are expressed as in eq. (1).

0014

[equation 1]

$$D(f,p)=\int_{-\frac{M}{2}}^{\frac{M}{2}}\int_{-\frac{N}{2}}^{\frac{N}{2}} g(x,y)\, e^{-j\frac{2\pi}{Fw}fx}\,dx\, e^{-j\frac{2\pi}{Pw}py}\,dy$$

0015

If the x-coordinate of the gradient center is x', and the shift in position from the gradient center is Δx, then x=Δx+x', so that eq. (2) is obtained.

0016

[equation 2]

$$\begin{aligned}D(f,p)&=\int_{-\frac{M}{2}}^{\frac{M}{2}}\int_{-\frac{N}{2}-\Delta x}^{\frac{N}{2}-\Delta x} g(\Delta x+x',y)\, e^{-j\frac{2\pi}{Fw}fx'}\,dx'\, e^{-j\frac{2\pi}{Pw}py}\,dy\; e^{-j\frac{2\pi}{Fw}f\Delta x}\\&=e^{-j\frac{2\pi}{Fw}f\Delta x}\int_{-\frac{M}{2}}^{\frac{M}{2}}\int_{-\frac{N}{2}-\Delta x}^{\frac{N}{2}-\Delta x} g(\Delta x+x',y)\, e^{-j\frac{2\pi}{Fw}fx'}\,dx'\, e^{-j\frac{2\pi}{Pw}py}\,dy\\&=e^{-j\frac{2\pi}{Fw}f\Delta x}D'(f,p)\end{aligned}$$

0017

Hence it is sufficient to perform the above phase correction, proportional to fΔx, on the echo data D'(f,p) measured at a position shifted by Δx from the gradient center. The case of movement in the phase-axis direction is similar; it is sufficient to perform the above phase correction, proportional to pΔy, on the echo data D'(f,p) measured at a position shifted Δy from the gradient center. Even if the order of phase encoding is not in the order of magnitude, corrections at each position are performed according to the position shifts Δx, Δy, so no problem arises. If the object for imaging G is only shifted by a fixed distance, linear phase correction is sufficient, and shifting after reconstruction is adequate; but in this method, the position of the object for imaging shifts with each phase encoding, so that square phase correction is used, and correction after reconstruction is not possible.

0018

As shown in Fig. 10, the oblique/three-dimensional integrated control unit 16 determines the tasks to be performed by the axial view-linked slice movement unit 13 and the sagittal/coronal SAT application unit 14, starts each of these, and collects data D'(f,p) (16A). That is, RF excitation/inversion is performed similarly to the case of axial views, spatial saturation pulse application is performed similarly to the case of sagittal/coronal views, and data D'(f,p) is collected. Next, for oblique imaging, the oblique/three-dimensional integrated control unit 16 divides the movement of the object for imaging G into components in the frequency-axis direction and in the phase-axis direction, and each is phase-corrected by the sagittal/coronal phase correction unit 15 to obtain data D(f,p). For three-dimensional imaging, [the oblique/three-dimensional integrated control unit 16] divides the movement of the object for imaging G into components in one frequency-axis direction and two phase-axis direction, and each is phase-corrected by the sagittal/coronal phase correction unit 15 to obtain data D(f,p). Then, control is returned to the system. For oblique imaging, the system takes the two-dimensional Fourier transform and reconstructs the image. For three-dimensional imaging, [the system] takes the three-dimensional Fourier transform and reconstructs the image.

0019

As is clear from the above explanation, by means of the image pickup device of the above embodiment, image pickup of axial images, sagittal images, coronal images, oblique images, or three-dimensional images can be performed by the MRI device 10, while continuously moving the object for imaging G. If the equipment is a specialized apparatus for image pickup only of axial images, the bore 10a may be made extremely short.

0020

Image pickup methods which do not use Fourier transforms, such as spiral scan and filtered back-projection methods, can be accommodated by changing the RF frequency for each view with respect to the imaging plane [Tr's note: It is not clear what relation the imaging plane has to the method used.], and in readout using a gradient magnetic field, by performing the above phase correction for each data point according to the readout direction (in the direction of the straight line from the origin in k-space to the echo data

point). In cases where the movement speed Gv is fast, or the echo time TE is long, it is preferable that "gradient moment nulling" or other movement correction be performed for axes having components in the movement direction. Even in the case of ultra-fast image pickup methods, when multishot methods are used in which RF excitation is applied separately a number of times, it is preferable that the correction of this invention be applied for each shot.

0021

Advantageous Result of the Invention

By means of the image pickup apparatus using an MRI device of this invention, image pickup can be performed using the MRI device while continuously moving the object for imaging. Hence the efficiency of image pickup can be improved.

Brief Description of the Drawings

Fig. 1 Schematic diagram of one embodiment of the image pickup apparatus using an MRI device of this invention

Fig. 2 Flowchart of the operation of the movement/image pickup simultaneous execution unit

Fig. 3 Explanatory diagram of the relation between the imageable region, data collection time, and movement speed

Fig. 4 Flowchart of the operation of the correction requirement judgment unit

Fig. 5 Flowchart of the operation of the axial view-linked slice movement unit

Fig. 6 Explanatory diagram of movement of a slice in axial imaging

Fig. 7 Flowchart of the operation of the sagittal/coronal SA[T] application unit and sagittal/coronal phase correction unit

Fig. 8 Explanatory diagram of movement of the object for imaging during sagittal/coronal imaging

Fig. 9 Diagram explaining the principle of phase correction in sagittal/coronal imaging

Fig. 10 Flowchart of the operation of the oblique/three-dimensional integrated control unit

Fig. 11 Schematic diagram of one example of a conventional image pickup apparatus using an MRI device

Explanation of Symbols

1 Image pickup apparatus using MRI device

10 MRI device

10a Bore

11 Movement/image pickup simultaneous execution unit

12 Correction requirement judgment unit

13	Axial view-linked slice movement unit
14	Sagittal/coronal SA[T] application unit
15	Sagittal/coronal phase correction unit
16	Oblique/three-dimensional integrated control unit
20	Belt conveyor
G	Object for imaging
Mw	Imageable region
Gw	Range for imaging
Mt	Time for collection of one image's worth of data
Gv	Movement speed
TR	Repetition time
Ms	Slice

Figure 1

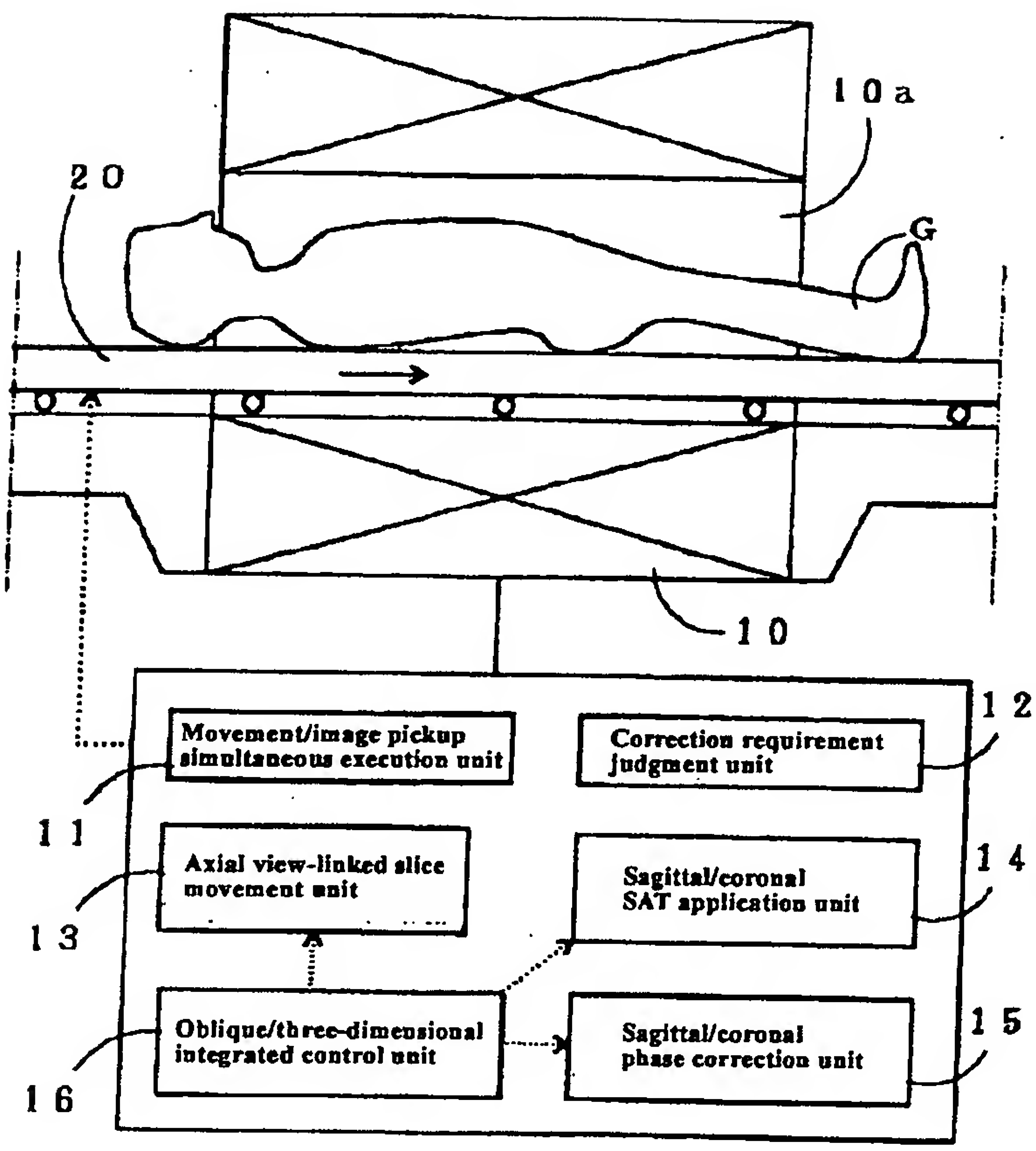


Figure 3

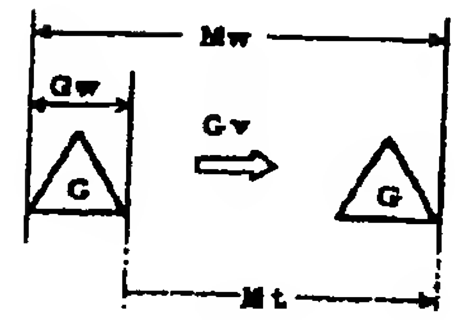


Figure 6

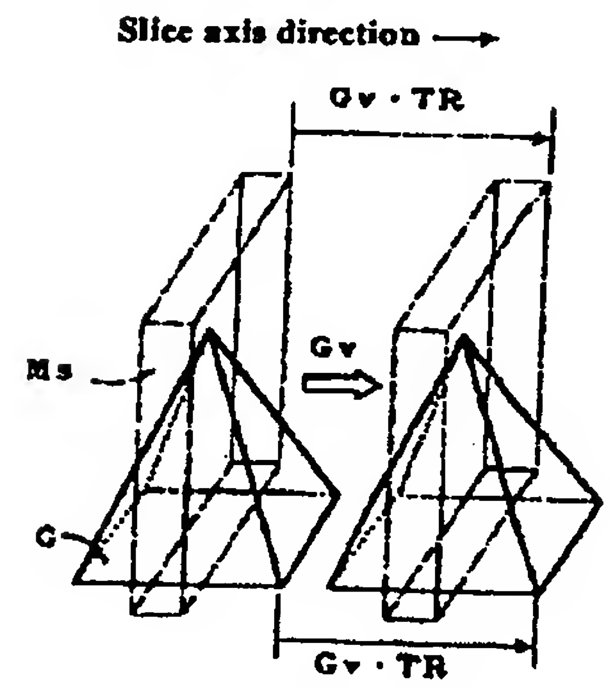


Figure 2

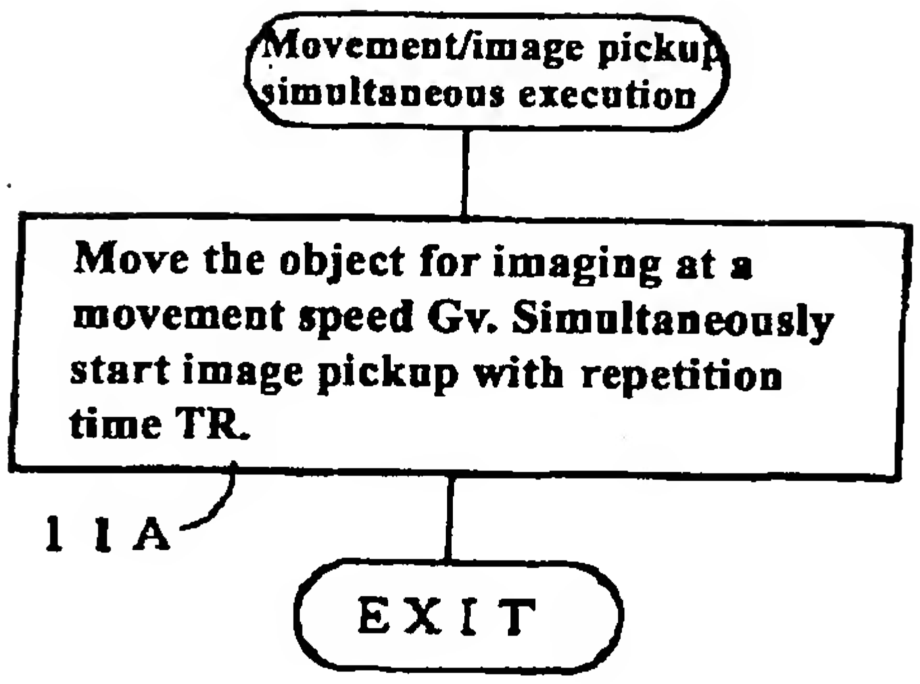


Figure 5

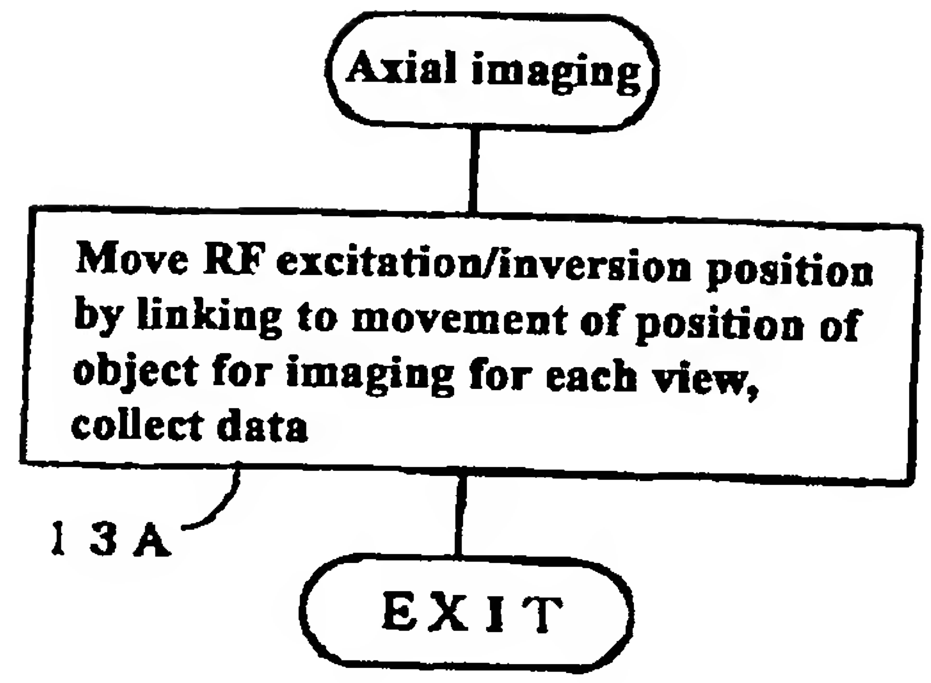


Figure 4

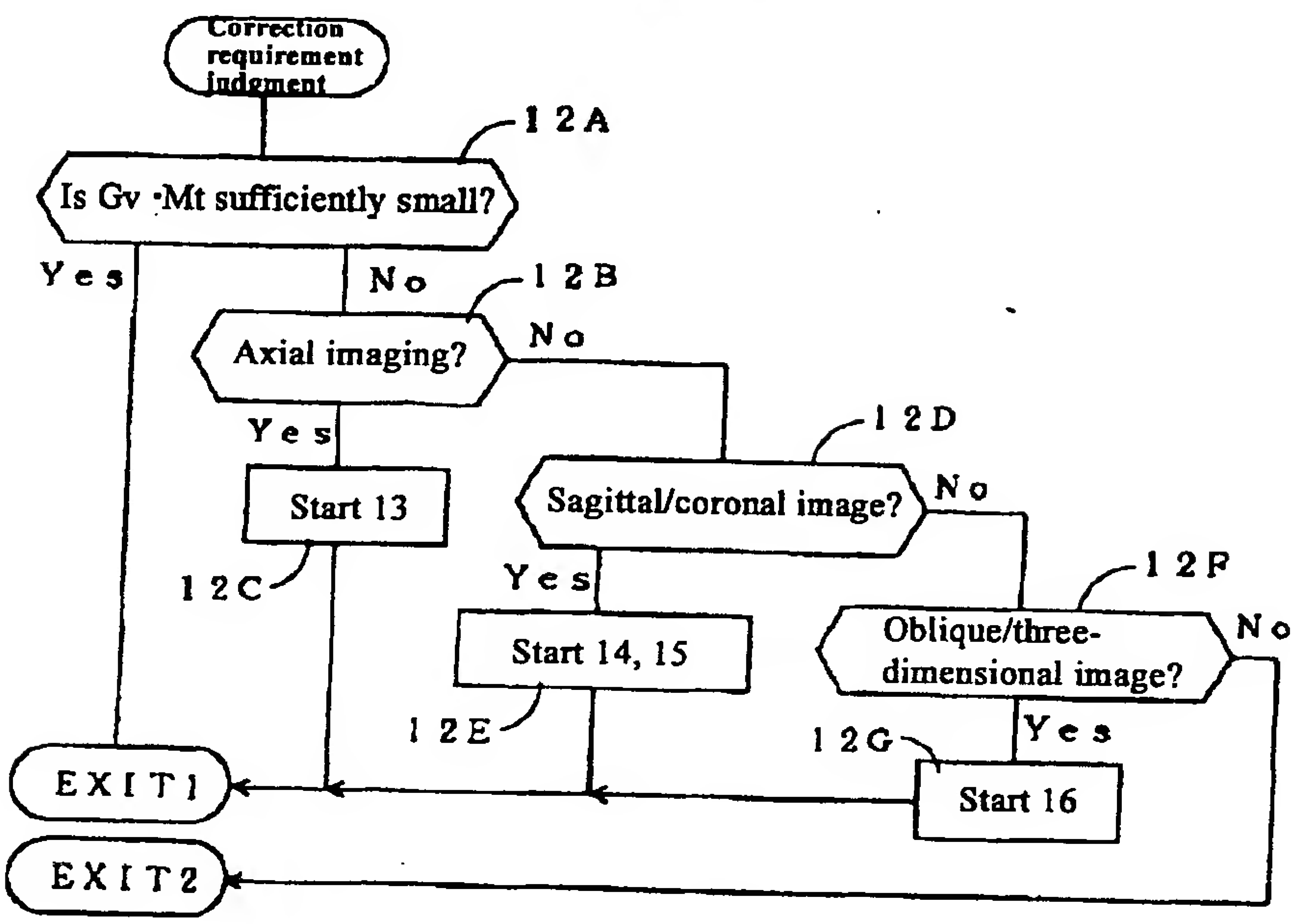


Figure 8

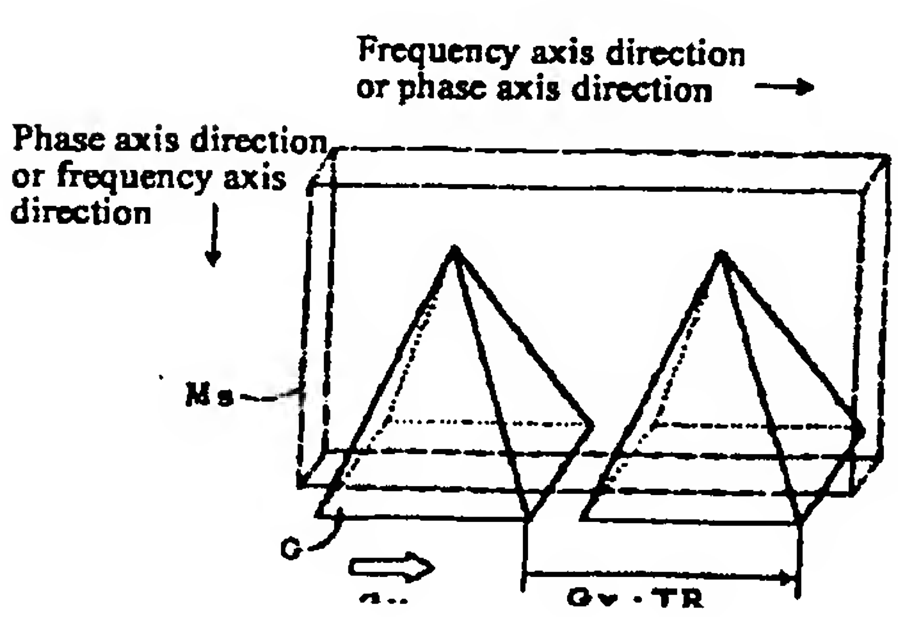


Figure 7

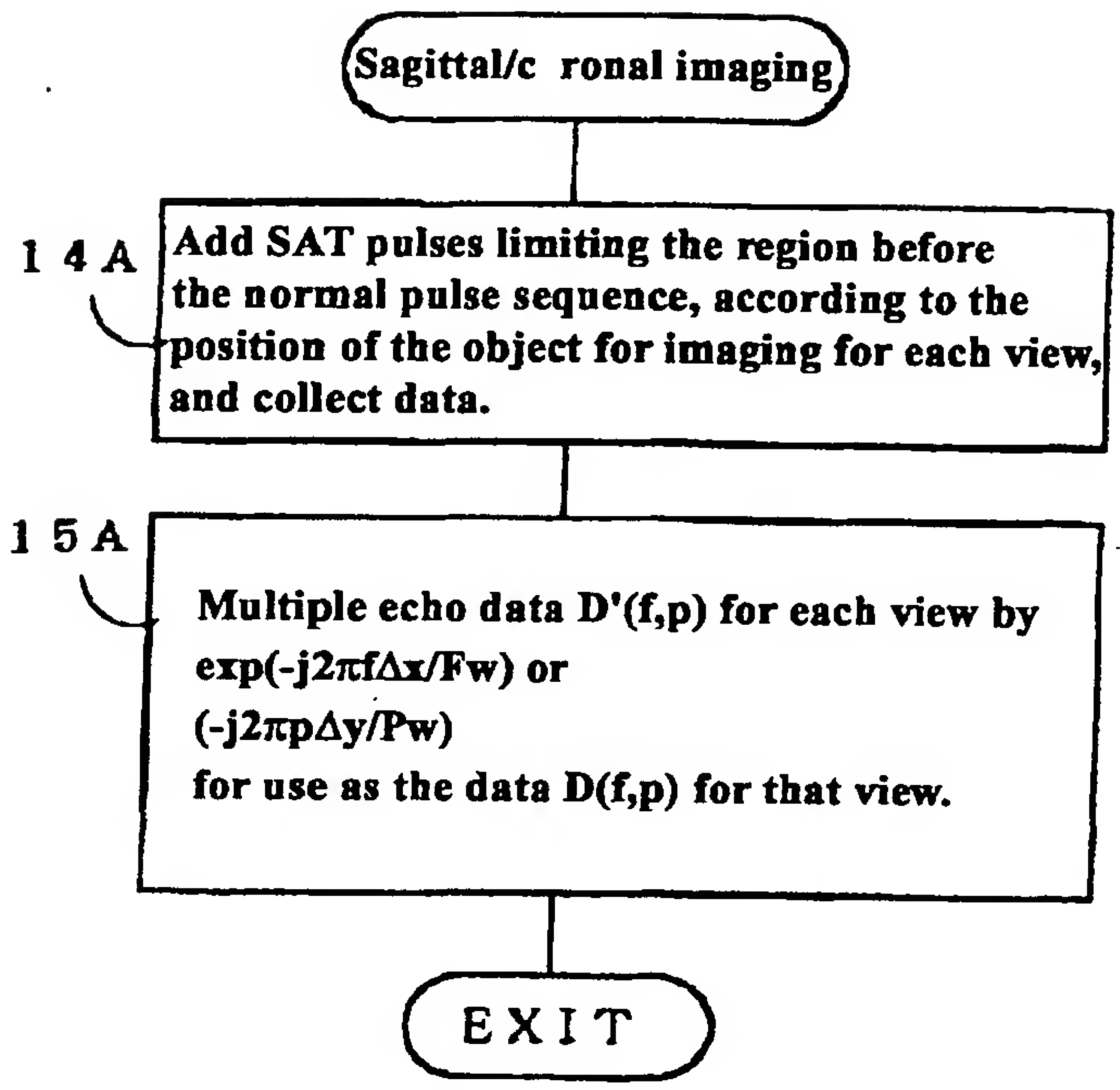


Figure 9

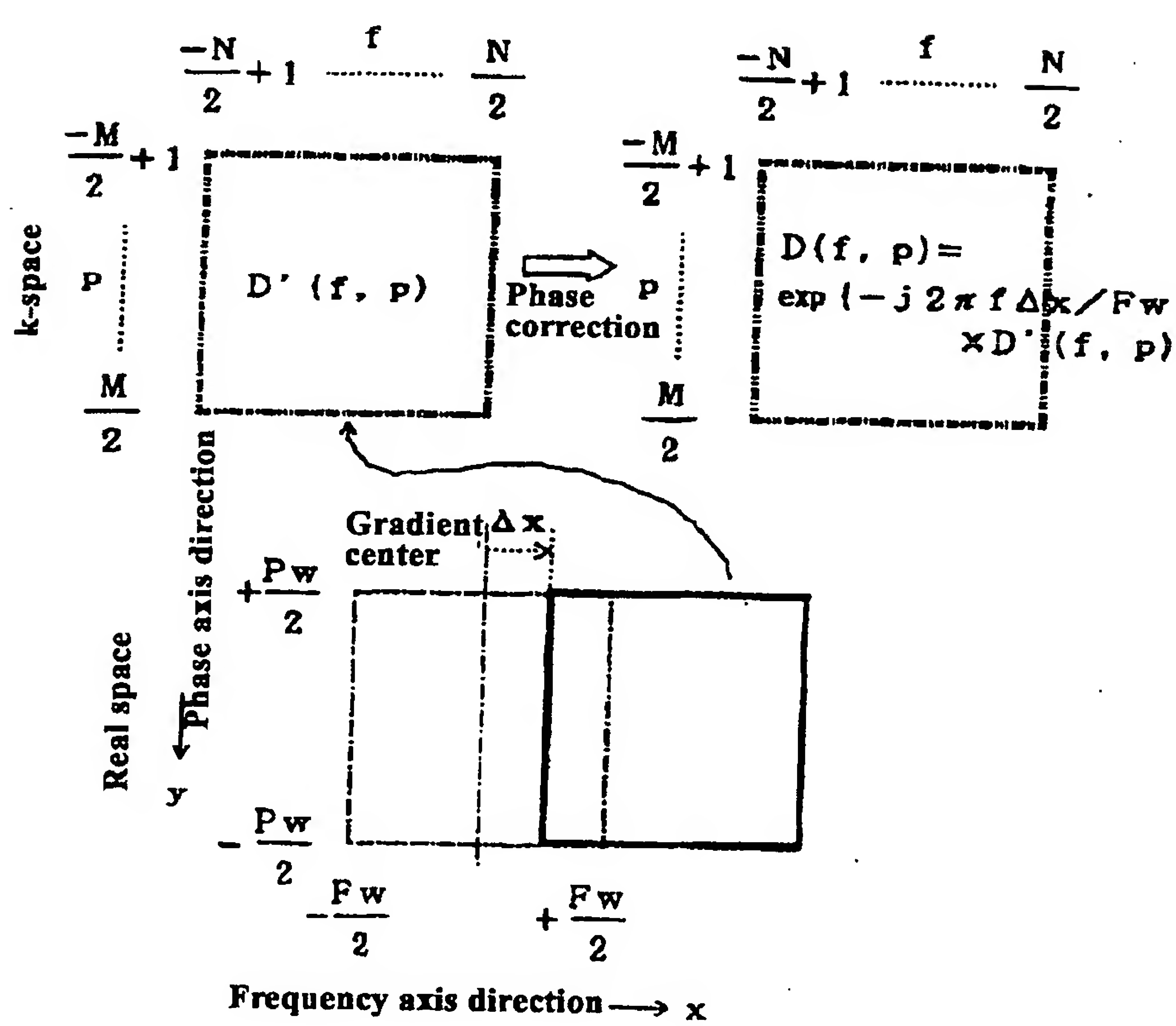


Figure 10

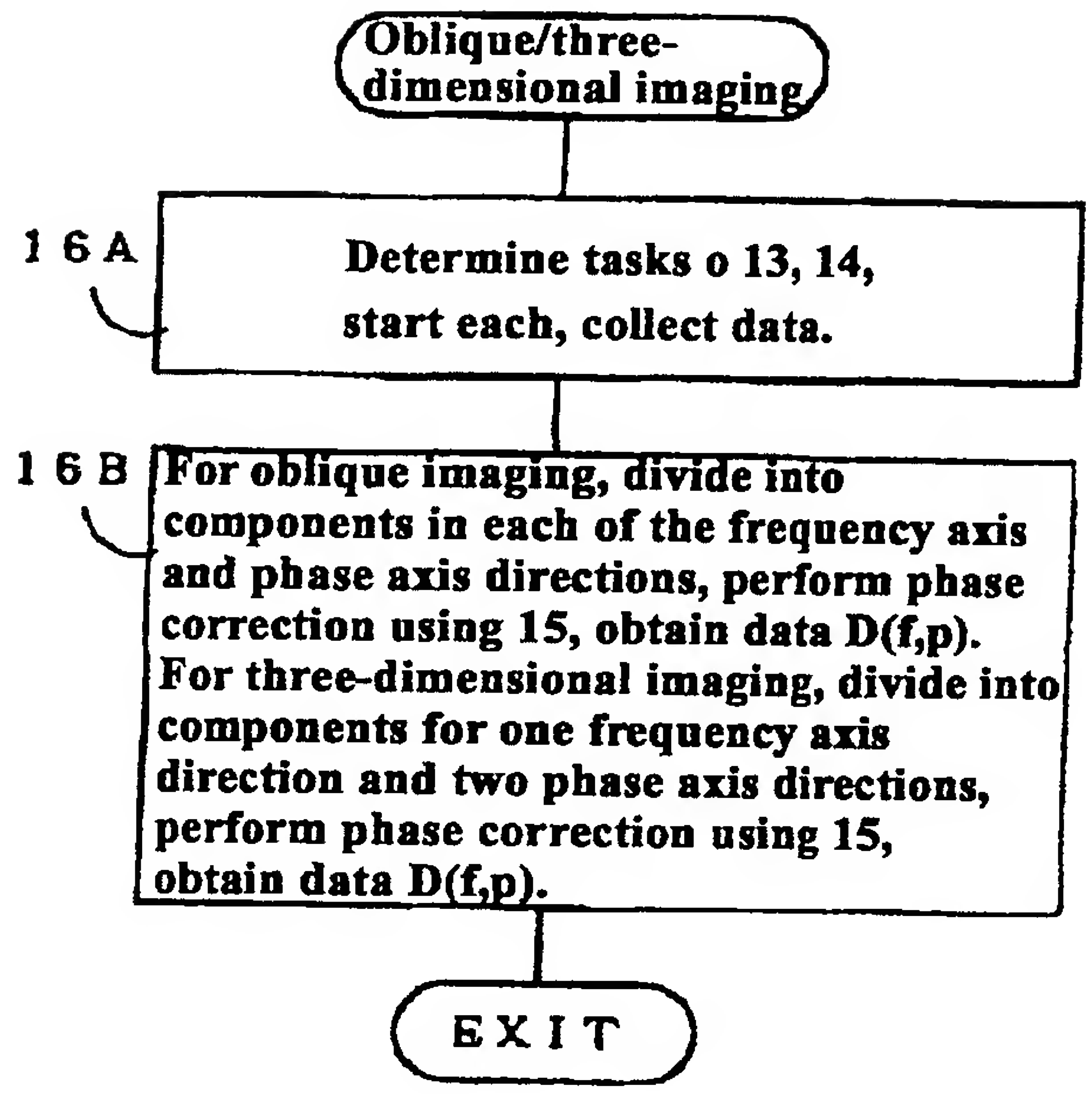
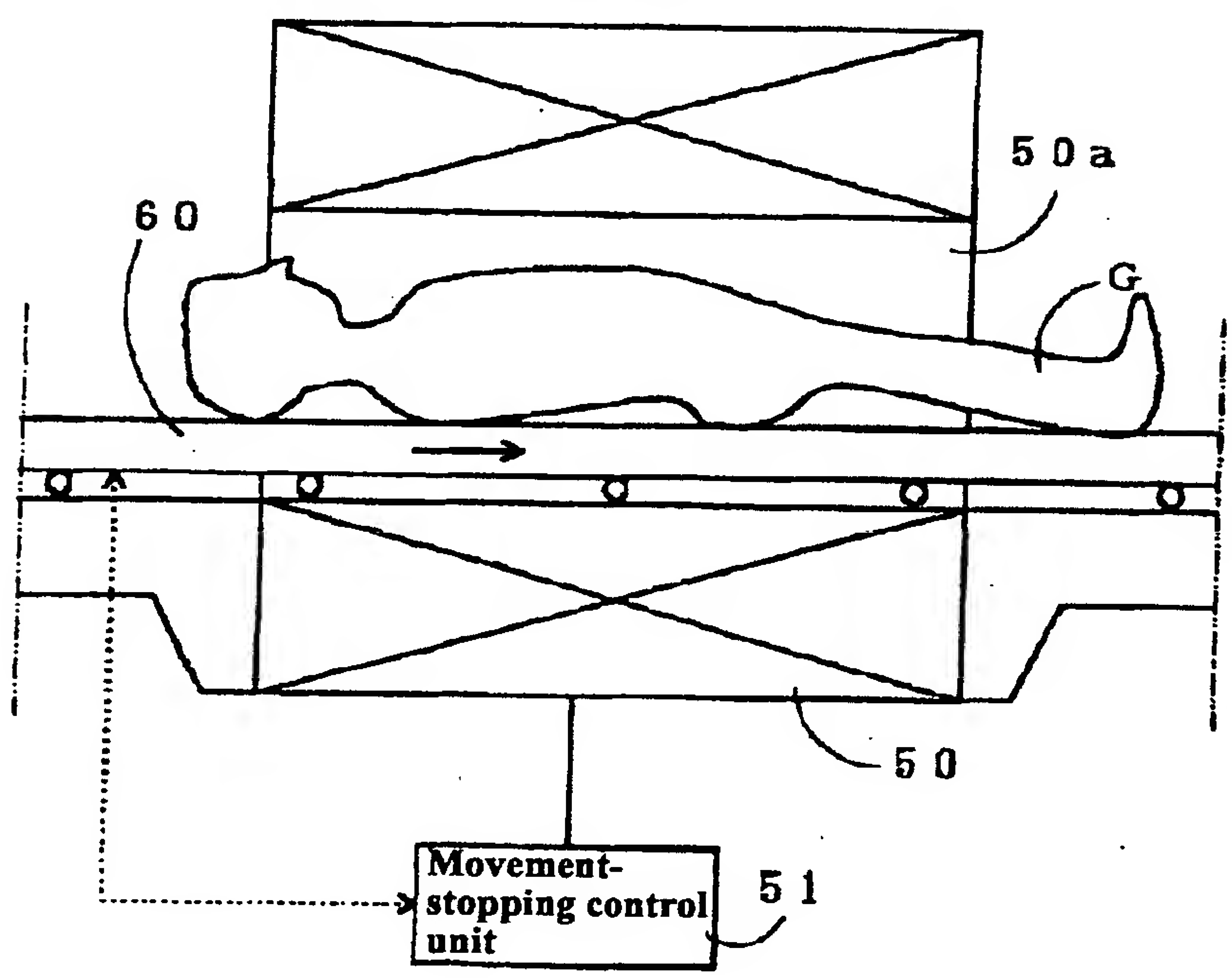


Figure 11



Gadolinium optimized tracking technique: A new MRA technique for imaging the peripheral vascular tree from aorta to the foot using one bolus of gadolinium.

K.Y. Ho, T. Leiner, M.H. de Haan, J.M.A. van Engelshoven. Department of Radiology, Univeristy Hospital Maastricht, Maastricht, The Netherlands.

Purpose

To develop a new technique with which the peripheral arteries of the legs can be imaged with one single bolus of Gd-dtpa.

Methods & materials

Fifteen healthy volunteers, who had no known vascular pathology underwent gadolinium enhanced MRA of the peripheral arteries from aorta to the foot on a conventional 1.5 tesla MR system, using the body coil for signal transmission and reception. The examination started with two Gd-dtpa arrival time sequences, one in the region of the knee (1 cc) and one in the region of the abdominal aorta (1 cc). Thereafter two sets of 3 scans were made with fast interscan table movement (14.4/5.7/50°/7.2 mm^3/43 sec per scan). Three pre-contrast scans of the pelvic, upper leg and lower leg region (≈ 2 min.) were subtracted from 3 scans during infusion of 38 cc of Gd-dtpa (≈ 2 min.). In total 120 centimetres of the legs vasculature was imaged. The MIP images were evaluated considering the contrast and signal to noise ratios (SNR). A vascular radiologist scored the images for the presence or absence of normal vascular morphology.

Results

All major peripheral arteries were identified by the vascular radiologist. The contrast and SNR calculations (range of contrast = 0.58 (aorta) to 0.86 (popliteal artery, range of SNR = 7 (lower leg) to 20 (upper leg) showed excellent vessel visibility. Although the lower leg had lower ratio figures, identifying the vessels was possible in all volunteers down to the ankle region.

Conclusion

The gadolinium optimized tracking technique can image the whole peripheral vascular tree in 2 x 2 minutes using only 40 cc of gadolinium. This technique allowed us to reduce overall patient handling time for imaging both legs on a conventional MR system to 30 minutes. Preliminary results in patients are in excellent accordance with conventional X-ray angiography, not only for the iliac and femoral regions, but also for the lower leg.

References

Prince-MR; Narasimham-DL; Stanley-JC; Chenevert-TL; Williams-DM; Marx-MV; Cho-KJ. Radiology. 1995 Dec; 197(3): 785-92.

Douek-PC; Revel-D; Chazel-S; Falise-B; Villard-J; Amiel-M. AJR-Am-J-Roentgenol. 1995 Aug; 165(2): 431-7.